Feb. 28, 1967 F. A. BURNE 3,306,353

HEAT EXCHANGER WITH SINTERED METAL MATRIX AROUND TUBES

Filed Dec. 23, 1964 2 Sheets-Sheet 1

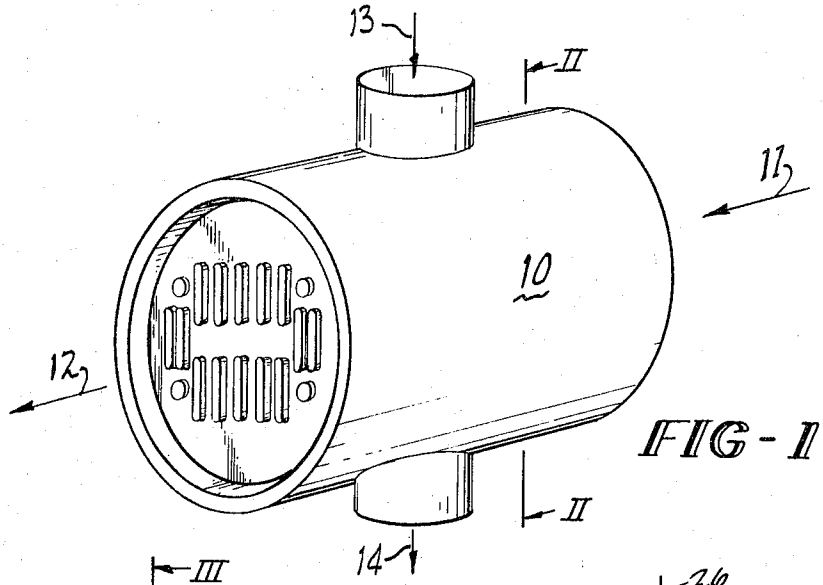


FIG-1

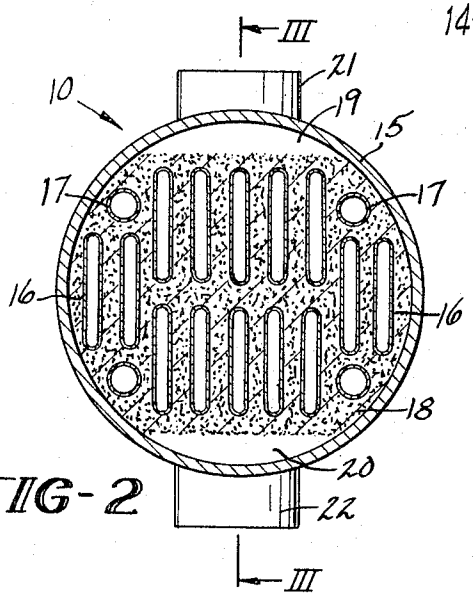


FIG-2

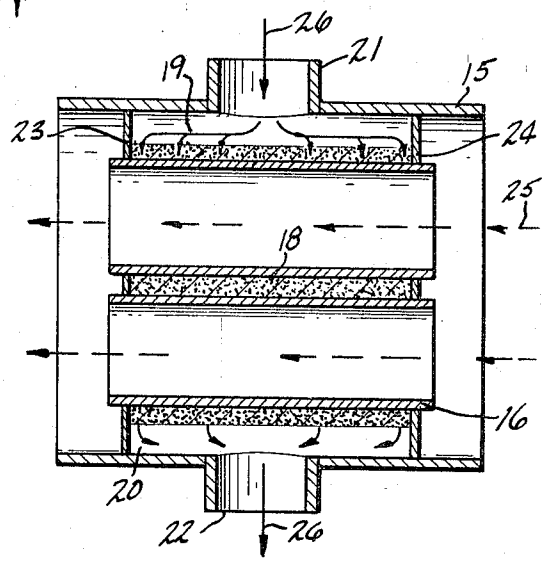


FIG-3

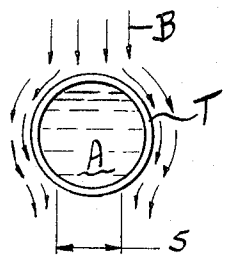


FIG-4

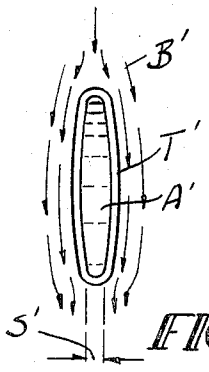


FIG-5

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HEAT EXCHANGER WITH SINTERED METAL MATRIX AROUND TUBES

Filed Dec. 23, 1964 2 Sheets-Sheet 2

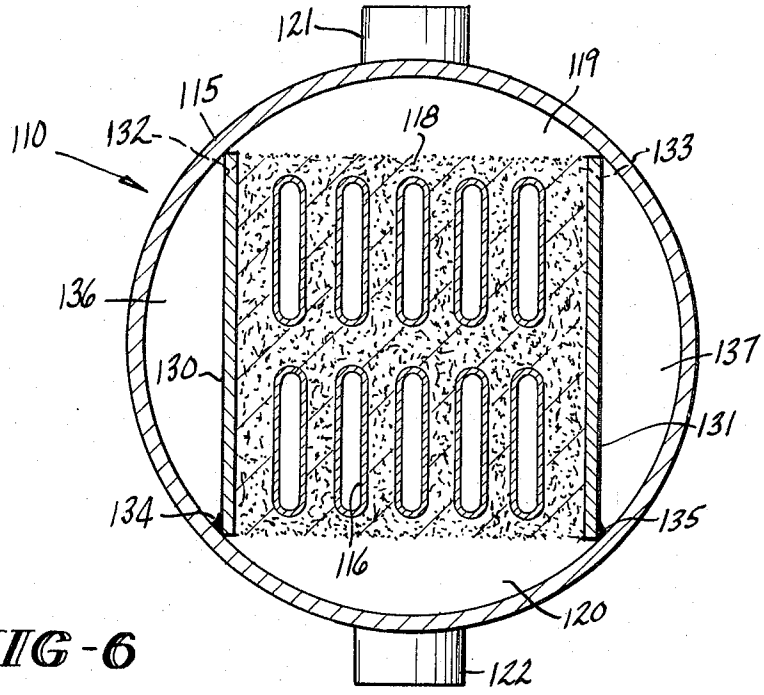


FIG-6

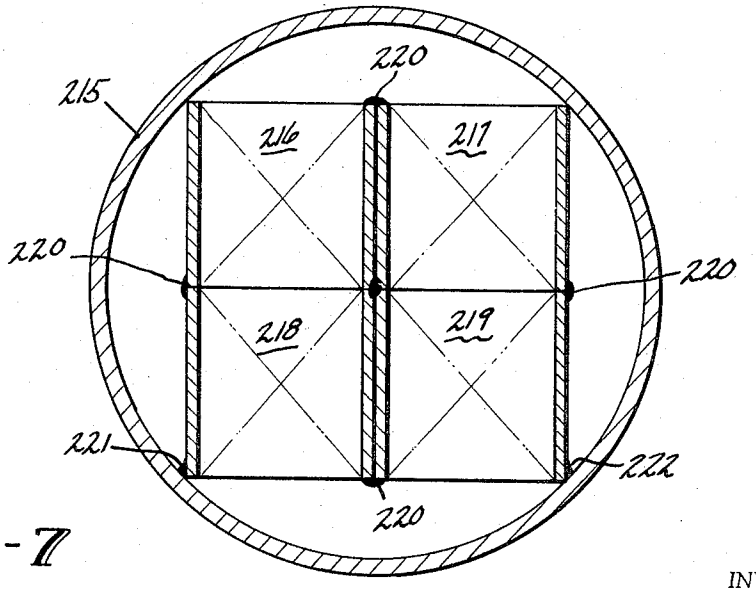


FIG-7

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HEAT EXCHANGER WITH SINTERED METAL MATRIX AROUND TUBES

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Filed Dec. 23, 1964, Ser. No. 420,567
6 Claims. (Cl. 165—164)

This invention relates to heat exchangers, and more particularly to an improved heat exchanger having a body of pervious material therein.

As is known in the heat exchanger art, the greatest heat exchange is achieved by providing the maximum possible area of heat exchange surface across which the desired heat exchange may take place. Various devices have been employed to so increase the area such as, for example, fins or corrugations across which pass the media between which the heat exchange is to take place. However, it has been found that greatly increased heat transfer surfaces can be achieved by instead employing a body of pervious material, or a porous body having interconnected voids. Such a body of pervious material presents a large number of faces for heat exchange purposes, as well as other advantages to be discussed shortly.

By the instant invention there is provided a unique configuration and arrangement of such a pervious body within a heat exchanger which has been tested and found to result in greatly increased heat exchange properties. The concept of the instant invention may be employed in heat exchangers of any desired shape, but is particularly adapted to tubular heat exchangers. As known in the art, the use of heat exchangers of a tubular configuration is highly advantageous in certain environments where it is desired that the heat exchange take place wholly within the exchanger. The tubular heat exchangers commonly in use in such an environment are of the type known in the art as "shell and tube," wherein a plurality of tubes conveying one heat exchange medium are arranged within a shell through which is circulated another heat exchange medium, with or without the use of baffles to direct the flow, which is substantially axial along the tubes.

In the concept of the instant invention there is provided a heat exchanger in which not only the heat exchange area is increased but the flow of one of the media is directed in a path between and around a series of inner tubes, the medium flow being substantially perpendicular to the axes of the inner tubes. The advantages resulting from such flow are achieved by the provision of a pervious body completely encasing the series of inner tubes. By a particular configuration and arrangement of the tubes and the pervious body, to be discussed hereinafter, space is provided within the heat exchanger to serve as distribution and collection manifolds for the heat exchange media resulting in the desired flow. Furthermore, the instant heat exchanger may be made sufficiently compact so that it may be used in "in-line" installations, for example, within a radiator hose of an automobile cooling system.

As will be understood, various combinations of metals may be utilized in forming the heat exchangers according to the intsant invention; and accordingly the solid portions and the pervious body may be of the same metal or alloy, or the pervious structure and the solid member may be comprised of different compositions. For example, both the pervious body and solid portions may be formed of the same stainless steels, coppers, brass, carbon steels, aluminums or various combinations thereof. As will be evident, the ultimate use of the resultant structure determines the specific combination of alloys to be employed.

The production of the pervious body is most flexible; for example, it may be produced by a process wherein particles, usually spherical, are poured by gravity into an appropriately shaped confined space and usually vibrated to cause the particles to compact uniformly. As is obvious, the choice of particle size will largely determine the size of openings in the resulting pervious body. The body of particles so packed is then treated in accordance with any of the well known metallurgy practices—e.g., sintering, welding; brazing or soldering employing an appropriate coating—to produce a metallic bond between the particles. Thus, there is provided a pervious body whose bulk density, or apparent density, is but a fraction of the density of the metal or alloy from which the particles are obtained. Furthermore, such process results in a metallic bond between the pervious body and solid material around or within the body.

While the above described process is preferred in the instant invention, other processes may be employed. For example, it is possible to blend intimately a particulate material with either a combustible substance or a soluble material whose melting point exceeds the sintering temperature of the particulate material. After the blend is compacted and treated to achieve a metallic bond, the combustible substance may be burned away or the soluble material removed by leaching or dissolving with a liquid. A still further method of producing the pervious body comprises melting a metal or alloy and casting it into the interstices of a loose aggregate of a particulate soluble material whose melting point exceeds that of the metal, preferably having a specific gravity of the molten metal. Upon solidification of the metal, a component is produced which contains the network of the soluble material interspersed within the solid metal which soluble material is thereupon removed by leaching or dissolving, leaving behind it interstices that interconnects and form a pervious network within the resultant metal body. A still further method of producing such pervious bodies comprises weaving or knitting metal wire into a mesh arranged in a plurality of layers. According to this process, a control of porosity is obtained by appropriate choice of wire diameters and openings arranged between adjoining wires as well as the juxtapositioning of superimposed layers of the woven or knit mesh.

It is to be understood that the concept of this invention need not be limited to the particular configuration indicated above. For example, a tube need not be exclusively employed; any desired shape of exchanger may be provided, with the inner tubes and pervious body shaped accordingly to fit. Furthermore, the tubes may be of any desired cross-section, any number of heat exchange media may be employed, the exchanger may be used for either heating or cooling, and the direction of flow of the heat exchange media may take a variety of patterns.

It is accordingly an object of this invention to provide a heat exchanger which is highly compact and yet capable of high efficiency and low pressure drop.

It is a further object of this invention to provide such a heat exchanger having a body of pervious material joined therein by a metallic bond.

It is a still further object to provide such a heat exchanger comprising a tubular member having a plurality of inner tubes bonded in a body of pervious material.

It is a still further object to provide such a heat exchanger which may be employed within a radiator hose of an automobile cooling system.

Additional objects and advantages will become apparent to those skilled in the art from a consideration of the details of several specific embodiments illustrated in the drawings, in which:

FIGURE 1 is a perspective view of a heat exchanger employing the concept of this invention,

FIGURE 2 is an axial cross-section of the heat ex-

changer of FIGURE 1, taken along the lines II—II thereof,

FIGURE 3 is a longitudinal cross-section of the heat exchanger of FIGURE 1, taken along the lines III—III of FIGURE 2,

FIGURE 4 is a diagrammatic view of a heat exchange medium flowing around a tube of circular cross-section,

FIGURE 5 is a diagrammatic view of a heat exchange medium flowing around a tube of substantially elliptical cross-section,

FIGURE 6 is a view similar to FIGURE 2, showing a second embodiment of the instant heat exchanger, and

FIGURE 7 is a diagrammatic view of the modular concept of the instant invention.

A first embodiment of heat exchanger according to this invention is shown in FIGURE 1, and is designated generally by **10**. A first heat exchange medium, for example the medium to be employed in heating or cooling, is introduced into the heat exchanger **10** at one end thereof, as shown by the arrow **11**, and exits from the opposite end thereof in the direction of the arrow **12**. A second heat exchange medium, for example the medium to be cooled or heated, enters the heat exchanger **10** through any suitable fitting in the direction of the arrow **13**, is circulated through the heat exchanger, and exits through a suitable fitting in the direction of the arrow **14**. It will be obvious that any desired media might be employed in the instant heat exchanger; for example, the medium introduced at **11** may be water and that introduced at **13** may be oil.

Referring now to FIGURE 2 of the drawings, it may be seen that heat exchanger **10** comprises an outer tube **15** and a plurality of inner tubes **16** and **17**. It will be obvious that the tubes **15**, **16**, **17** may take any desired configuration. However, the tube **15** is shown as being of a circular cross-section, the tubes **16** of substantially elliptical cross-section, and the tubes **17** of a circular cross-section, all for reasons to become evident shortly. Surrounding the inner tubes **16** and **17** and joined to such tubes by a metallic bond is a body of pervious material **18**. The pervious body **18** is formed in such a manner, to be discussed hereinafter, that there exists at an upper portion of the heat exchanger **10** a void **19**, and at the lower portion thereof a void **20**.

As can best be seen in FIGURE 3, communicating through the upper portion of heat exchanger **10** is an inlet fitting **21** which communicates with void **19**, and at a lower portion of the heat exchanger there is located an outlet fitting **22** which communicates with void **20**. Referring still to FIGURE 3, it may be seen that each of the inner tubes **16** and **17** is secured and sealed at its opposite ends within suitable apertures of two header plates **23** and **24**. Header plates **23** and **24** are in turn secured and sealed to the inner periphery of tube **15**.

As shown, the heat exchanger **10** may be used in a radiator hose of an automobile cooling system, and accordingly there is no need to seal the ends of the heat exchanger as shown in FIGURE 3. It will be evident that portions of a radiator hose may be merely slipped around the opposite ends of the heat exchanger, and secured in any appropriate fashion, as by standard hose couplings. However, the heat exchanger shown need not be used exclusively within a hose; by connection of suitable end plates, provision may be made for connection of additional piping means for circulation of the first medium.

In either case, it will be evident that one of the heat exchange media may be circulated longitudinally through the heat exchanger **10**. Such a condition is shown in FIGURE 3, wherein the dashed arrows **25** represent the flow of one heat exchange media, for example the water of an automotive cooling system. The second heat exchange medium, for example oil, may be introduced through the inlet fitting **21** and follow the path of the solid arrows **26**. Specifically, the second heat exchange

medium would enter through inlet fitting **21**, flow within the void **19** distributing along the length thereof, through the pervious body **18** around the tubes **16** and **17**, collecting in the void **20**, thence out through outlet fitting **22**. It will be evident that void **19** forms a distribution manifold for the entering medium, there being less resistance to flow in such an area than in the pervious body. After distribution along the entire length of manifold **19**, the flow would then necessarily be through the pervious body **18** downward, between and around the tubes **16** and **17**. Void **22** would consequently serve as a collection manifold, the fluid collecting and exiting through outlet **22**. Obviously, suitable fittings may be connected to fittings **21** and **22** for connection of appropriate piping of the second medium. Thus, it can be seen that in the instant heat exchanger, the flow of the second heat exchange medium is substantially perpendicular to the flow of the first heat exchange medium, in contrast to heat exchangers presently in use wherein the flow paths of the two media are substantially parallel.

As indicated hereinbefore the inner tubes **16** and **17** may take any desired configuration; however, the configurations shown have been chosen to achieve maximum heat exchange results. Specifically, it has been found that tubes having a substantially elliptical cross-section yield advantages not obtainable by tubes of the conventional circular cross-section. Such a cross-section may be obtained by flattening a conventional tube until the tube assumes a nearly rectangular cross-sectional configuration. A tube having such a configuration is desirable for a number of reasons. Firstly, such a configuration presents a large surface area relative to its frontal area. As known in the art, the application in which the heat exchanger is to be used and the allowable pressure drop will dictate the flow through the interior of the tube. This flow will in turn dictate the frontal area of the tube. By forming the tube in the configuration described, an optimum periphery of tube wall is presented for any given frontal area. Thus, this surface area is considerably increased over conventional configurations, for example a tube of circular cross-section.

Additionally, the substantially elliptical configuration achieves desirable results regarding the medium flowing interiorly of the tube. In a tube of, for example, circular cross-section, the heat exchange taking place is inherently greatest in the regions near the periphery of the tube. Accordingly, the medium flowing near the center of the tube performs little heat exchange, and passes through the tube without performing its intended function. However, in a substantially elliptical tube, the amount of medium not taking part in the heat exchange is materially reduced, since a greater portion of the medium is directly adjacent the outer wall of the tube.

Furthermore, when the flow of the second heat exchange medium is perpendicular to the axis of the tubes, a substantially elliptical tube provides additional advantages. Referring now to FIGURE 4 of the drawings, there is shown diagrammatically a tube T of circular cross-section, through which flows a first heat exchange medium A. Flowing perpendicunlar to the axis of tube T is a second heat exchange medium represented by the arrows B. As shown, the heat exchange medium B will pass around the tube T, performing its heat exchange function, and flow downwardly on toward the next tube. However, as the medium B passes around the tube T, the flow will inherently miss a portion at the lower end of tube T represented by the distance S. In such an area, little if any heat exchange may take place. This area can be substantially reduced by forming the tube in a substantially elliptical configuration. Thus, as seen in FIGURE 5, the tube T' has a first heat exchange medium A' flowing therethrough. The second heat exchange medium B' flows about the tube T' and, due to the reduction in the disturbance of the flow of medium B', the area S' is substantially smaller than area S of FIGURE 4. Thus, it

will be evident that a greater amount of heat exchange takes place at the lower portion of the substantially elliptical tube than with a tube of circular cross-section. In FIGURES 4 and 5, the pervious body has been deleted for the sake of clarity. The presence of such a body would not materially alter the flow characteristics discussed above.

Again in applications where the flow of the second heat exchange medium is perpendicular to the axis of the tubes, substantially elliptical tubes provide a still further advantage. As indicated hereinbefore, the pervious body surrounding the tubes acts as heat exchange fins for the tubes. It is well known in the art that there exists an aptimum fin distance, or optimum fin length, beyond which little heat exchange can take place. Thus, for two tubes of circular cross-section side by side, the distance between corresponding adjacent points of such tubes will of course vary. Thus, if the two closest points of the adjacent tube be the optimum fin distance, then any fin distance in excess of this distance, as for example that distance between the two furthermost spaced points of the adjacent tubes, performs reduced heat exchange. Similarly, if the distance between the two furthermost spaced points of the adjacent tube be the optimum fin distance, then the distance between the two most closely spaced points would be less than the optimum fin distance. However, for adjacent tubes of substantially elliptical cross-section, the distances between adjacent points of the two tubes is more nearly constant, and hence may be more nearly equal to the optimum fin distance throughout.

The above-noted advantages resulting from the use of tubes of a substantially elliptical cross-section yield surprising heat exchange results. Of course, such a tube is less able to withstand high pressures exteriorly than is a tube of circular cross-section. However, in the instant device, it will be recalled that the tubes are joined by a metallic bond within a pervious body. Such a bond holds the walls of the substantially elliptical tubes in tension and increases the stability of such tubes in withstanding high pressures.

Referring now again to FIGURE 2 of the drawings, it will be seen that the particular arrangement of the inner tubes **16** and **17** provides all of the advantages above noted. The substantially elliptical tubes **16** are so arranged that the distance between corresponding adjacent points of any two adjacent elliptical tubes is very close to the optimum fin distance. The flow of the second heat exchange medium, which has been noted to be from manifold **19** downwardly to manifold **20**, is perpendicular to the axis of the tubes **16** and **17**. Accordingly, the noted advantages resulting from the substantially elliptical configuration are also obtained. Obviously, for an outer tube **15** of circular cross-section, which is the most usual form, use of substantially elliptical tubes **16** will necessarily leave some areas of the pervious body **18** which represent a width greater than the optimum fin distance but a height greater than the height of a tube **16**. In such an area, tube **17** of a circular cross-section may be employed if so desired, the distance between the periphery of circular tube **17** and that of the adjacent tube **16** being as nearly possible the optimum fin distance.

Considering now the method by which the instant heat exchanger may be produced, it will be evident that the pervious body **18** may be formed about the tubes **16** and **17** in any of the methods indicated hereinbefore. The tubes **16** and **17** may be positioned in the apertures of end plate **23** and **24**, and the resulting assembly situated in an appropriate mold. Thereafter, the particles of pervious body may be poured into the mold, with provision having been made for leaving voids **19** and **20**. Following any of the metallurgical processes indicated hereinbefore, a metallic bond may be created between the tubes and the particles of the pervious body, as well as between each of the particles of the pervious body. The assembly may then be inspected, and the openings of header plates **23** and **24** through which the tubes pass may be appropriately sealed if such a seal has not been accomplished by the preliminary joining process. The header plates may then be suitably secured within tube **15** and appropriately sealed. Fittings **21** and **22** may be added at any stage of the manufacture, and any further end fittings added as needed.

Alternatively, the tubes may be positioned within the header plates **23** and **24**, the resulting assembly situated within the tube **15**, and supported by an appropriate mold. Portions of one of the header plates may be apertured so that the particles of pervious body may be inserted therethrough and a channel core may be provided. The resulting assembly may then be treated in accordance with any of the foregoing methods to simultaneously create a metallic bond (A) among the particles of the pervious body, (B) between the tubes **16**, **17** and the header plates **23** and **24**, (C) between the pervious body and each of the tubes **16** and **17**, (D) between the pervious body **18** and the header plates **23** and **24**, and (E) between the header plates **23** and **24** and the inner periphery of tube **15**. Following such treatment, the apertures of the header plates through which the particles of pervious material **18** and core were introduced may be resealed. As in the first method of manufacture, the fittings **21** and **22** might be added at any stage of the procedure, and any further end fittings could be added after the initial treatment.

A second embodiment of heat exchanger according to this invention is depicted in FIGURE 6, and is designated generally by **110**. It will be understood that the exterior appearance of the heat exchanger **110** will be generally similar to that shown in FIGURE 1, and that FIGURE 6 is a cross-sectional view similar to FIGURE 2. The tubes **116** are analogous to the tubes **16** of the first embodiment and, while not shown, it will be evident that the tubes **116** are secured within the outer tube **115** between header plates similar to plates **23** and **24** of the first embodiment, see FIGURE 3 of the drawings. Similarly, it will be understood that the tubes **116** convey a second heat exchange medium and the outer tube **115** conveys the first heat exchange medium, which is introduced through a suitable inlet **121** and exits through a suitable outlet **122**. Again, similar to the first embodiment, a pervious body **118** completely surrounds the tubes **116**.

Referring now to the differences between the second embodiment and the first, it may be seen in FIGURE 6 that the pervious body **118** of the second embodiment is so formed as to be rectangular in cross-section, for reasons to become evident shortly. Pervious body **118** is formed about the tubes **116** in any of the methods indicated hereinbefore so as to achieve a metallic bond between (A) the various particles of the pervious body, and (B) between the pervious body and each of the tubes. Additionally, the rectangular body is formed so as to include two non-pervious plates **130** and **131** on opposite side faces of the pervious body **118**. Plates **130** and **131** may be of any desired construction; thin sheets of metal have been tested and found to be satisfactory. Plates **130** and **131** may be joined to the pervious body **118** in any conventional fashion, as by supporting the plates in a suitable fixture during the processing of the pervious body **118**. At some portion along the longitudinal length of each of the plates **130** and **131** there is formed apertures **132** and **133**, respectively.

Thus, the rectangular body **118** with the tubes **116** joined therein, and the plates **130** and **131** joined thereto, may be fabricated as a modular unit apart from the tube **115**. Subsequently, the resulting unit may be positioned within a tube **115** and secured therein as by joining lower portions of plates **130** and **131** to the tube wall, as at **134** and **135**, as well as securely sealing the periphery of each of the header plates to the interior of tube **115**.

Following insertion of the module into tube **115**, it will be evident that the space adjacent the upper face of the

pervious body **118** forms a manifold **119**, analogous to manifold **19** of the first embodiment, and the space below the lower face of the pervious body **118** forms a manifold **120**, analogous to manifold **20** of the first embodiment. Thus, as in the first embodiment, the first heat exchange medium entering through inlet **121** distributes longitudinally along manifold **119**, is forced through the pervious body **118**, collecting in the manifold **120**, thence exiting through outlet **122**. Referring momentarily to FIGURE 2 of the drawings, a disadvantage of the heat exchanger there shown is that it is highly difficult to achieve a secure seal between pervious body **18** and the interior of tube **15** in the portion between manifolds **19** and **20**. Any space between the pervious body and the wall becomes a path of least resistance and the first heat exchange medium will flow through such a space and hence "bypass" the intended route through the pervious body. Referring again to FIGURE 6, such bypass is effectively eliminated in the second embodiment. As noted above, the lower portions of plates **130** and **131** along the full length thereof are effectively sealed to the tube wall **115**. Were the upper portions of the plates **130** and **131** also similarly secured, the high pressure on the insides of these plates would force them outward, leaving a space between the plates **130** and **131** and the pervious body **118**, resulting in the unfavorable bypass indicated above. Accordingly, the upper portions of plates **130** and **131** are not sealed to the tube **115**; instead, they are apertured as at **132** and **133**. Portions of the first heat exchange medium, upon initial introduction into the tube **115**, will flow through the apertures **132** and **133** into the spaces between plates **130** and **131** and the adjacent portions of tubes **115**, such spaces being referenced by the characters **136** and **137**. These spaces form "dead areas" or pressure equalization chambers to prevent separation of the plates **130** and **131** from pervious body **118**. As noted, the first heat exchange medium introduced will flow into the chambers **136** and **137**; thereafter, this fluid is trapped within such chambers and performs no heat exchange function. However, the presence of the medium in each of the chambers **136** and **137** equalizes the pressure on opposite sides of each of the plates **130** and **131**, the pressure of the first heat exchange medium flowing through the pervious body **118** being substantially the same as that trapped in the chambers **136** and **137**.

The modular construction noted above is further advantageous in that construction of heat exchangers of various sizes is materially facilitated. Thus, any number of heat exchange modules similar to that described above may be combined for use in tubes large enough to accommodate, or to require, more of the inner tubes **116**. Obviously the modules may be combined in a variety of fashions, that depicted in FIGURE 7 being merely exemplary, where there is shown, on a reduced scale, a larger tube **215**. Interiorly of the tube **215** are situated a plurality of modules **216**, **217**, **218** and **219**, depicted diagrammatically for sake of clarity. The modules **216**, **217**, **218**, **219** may be joined together in any suitable fashion, as by welding at the various juxtaposed faces as shown at **220**. As was the case when employing only one module, lower portions of the modular assembly which contact the inner face of tube **215** are suitably joined along their entire length, as at **221** and **222**. The functioning of the modular assembly will thus be analogous to that discussed above with regard to a single module used alone.

As will be obvious to those skilled in the art, the perpendicular flow of the second heat exchange medium achieved by the instant device, together with the precise positioning of the internal tubes, attains a high degree of heat exchange with a minimum of pressure drop. The precise flow indicated distributes the second medium over the entire pervious structure in a uniform manner over a greatly increased heat exchange surface. The construction of the pervious body, as well as of the tubes, will be dictated by the contemplated use of the exchanger dependent upon such factors as the thermal conductivity, specific heat, viscosity, and corrosive nature of the fluid, the presence of clogging solids in the fluid, and tolerable pressure drop.

It is to be understood that the invention is not limited to the illustrations described and shown herein which are deemed to be merely illustrative of the best modes of carrying out the invention, and which are are susceptible of modifications of form, size, arrangement of parts and detail or operation, but rather is intended to encompass all such modifications which are within the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A tubular heat exchanger for circulation of a plurality of heat exchange media, comprising

(A) a first tubular member for conveying a first heat exchange medium,

(B) a plurality of second tubular members for conveying a second heat exchange medium, disposed within said first tubular member, said second tubular members having a substantially elliptical cross section, said elliptical cross section having a long dimension, means for directing said second heat exchange medium to one inlet end of said second tubular members, and means for collecting said second heat exchange medium at an opposite, outlet end of said second tubular members, the longitudinal axis of said second tubular members being in parallel relationship to each other and to the longitudinal axis of said first tubular member, the distance spacing adjacent tubes being constant for essentially the entire length of the said long dimension of said elliptical cross section, whereby the optimum fin distance for the said second tubular members is achieved,

(C) a pervious body filling the spaces between adjacent of said second tubular members, and between said second tubular members and said first tubular member, said pervious body being between the said inlet and outlet means of the said second tubular members, and being joined to said second tubular members and to said first tubular member by a metallic bond and comprising:

(1) a first void located between said pervious body and said first tubular member and extending along the full longitudinal length of said pervious body, means for directing said first heat exchange medium only to said first void thereby effecting controlled distribution of said first heat exchange medium through said pervious body in a path between said second tubular members,

(2) a second void located between said pervious body and said first tubular member and extend-ind along the full longitudinal length of said pervious body for controlled collection of said first heat exchange medium passing through said pervious body,

(3) said pervious body between said first void and second voids thereof being of a cross-section matching the cross-section of said first tubular member,

whereby said first heat exchange medium passes through said first tubular member and between said plurality of second tubular members in a path perpendicular to the longitudinal axis of said second tubular members.

2. A heat exchanger according to claim **1** further characterized in that all the second tubular members have essentially the same cross section, the heat exchanger also including a plurality of third tubular members within said pervious body, said third tubular members being of a circular cross-section with their longitudinal axes in parallel relationship to the longitudinal axes of said second tubular members, said third tubular members being

disposed in cross sectional areas of said pervious body adjacent said first conduit where said second tubular members would not fit.

3. A heat exchanger for circulation of a plurality of heat exchange media, comprising

(A) a first conduit means for conveying a first heat exchange medium,

(B) at least one heat exchange module secured within said conduit, said module comprising

(1) a plurality of tubular conduit means for conveying a second heat exchange medium,

(2) a pervious body surrounding said plurality of tubular conduit means and joined thereto by a metallic bond, said pervious body being of a substantially rectangular cross-section,

(3) a pair of non-pervious plates on opposed side faces of said pervious body, said plates being located within said first conduit, said plates being parallel to the direction of flow of said first heat exchange medium and parallel to the said plurality of tubular conduit means,

(4) aperture means in said non-pervious plates allowing said first heat exchange medium to pass therethrough, whereby the pressure on opposite sides of each of said plates is substantially equalized,

(C) inlet means in said first conduit means adjacent an upper face of said module,

(D) outlet means in said first conduit means adjacent a lower face of said module,

whereby said first heat exchange medium passes through said module from an upper face thereof to a lower face thereof, flowing around said tubular conduit means in a direction perpendicular to the longitudinal axes thereof.

4. A heat exchanger according to claim 3 including a plurality of said modules joined together in operative relationship.

5. A heat exchange module for insertion in a conduit adapted to convey a first heat exchange medium, said module comprising

(A) a plurality of tubular conduit means for conveying a second heat exchange medium,

(B) a pervious body surrounding said plurality of tubular conduit means and joined thereto by a metallic bond, said pervious body being of a substantially rectangular cross-section,

(C) a pair of non-pervious plates on opposing side faces of, and in intimate contact with, said pervious body, said plates surrounding said tubular conduit means on the two sides of said tubular conduit means which are parallel to the longitudinal axis of said tubular conduit means, and

(D) aperture means in each of said non-pervious plates to allow passage of said first heat exchange medium therethrough, whereby the pressure on opposite sides of each of said plates may be substantially equalized.

6. A heat exchange module according to claim 5 wherein said tubular conduit means are each of a substantially elliptical cross-section and the distances between corresponding adjacent points on the periphery of adjacent tubes are substantially equal.

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